Incidence, legislations and strategies of control of mycotoxins in North African countries

[1,2]*Lahouar, A., [1]Jedidi, I., [1]Said, S. and [2]Sanchis, V.

[1]Laboratory of Biochemistry, Unity of Mycotoxicology, Faculty of Medicine of Sousse, University of Sousse, Mohamed Karoui, 4002, Sousse, Tunisia.

[2]Food Technology Departement, University of Lleida, XaRTA-UTPV, Agrotecnico center, Rovira Roure 191, 25198, Lleida, Spain.

Corresponding author: The University of Sousse, The Faculty of Medicine, Laboratory of Biochemistry, Unity of Mycotoxicology, Tunisia. Tel: (+216) 96767243. Fax: (+216) 73224899.

E-mail address: amanilahouar@yahoo.fr

Abstract

Mycotoxins are natural food and feed contaminants mainly produced by filamentous and ubiquitous fungi of genera *Aspergillus*, *Penicillium* and *Fusarium*. Due to the high stability of mycotoxins, contamination can occurs in the field, during storage, processing and post-processing steps, under favorable conditions of temperature and water activity. These compounds pose serious economic and health problems worldwide and show different toxicological effects in humans and animals. North African populations are exposed to the risk of mycotoxins due to consumption of contaminated food. These countries are surrounded by Mediterranean Sea and have a climate characterized by high humidity and temperature, which probably favors the growth of molds. During the last decades, many studies have reported the occurrence of different mycotoxins in food commodities in North African countries. Tolerable limits for mycotoxins have been established in these countries but legislations do not include all mycotoxins. In addition, researchers try to establish strategies to prevent and reduce mycotoxin contamination, but studies still rare and not include all mycotoxins and toxigenic fungi. This review presents an overview of the main investigations about the occurrence of mycotoxins and toxigenic mycobiota in food commodities commercialized in North African countries and the regulation limits which are in force in these countries.

Keywords: Mycotoxins, occurrence, fungi, legislation, control

Introduction

The problem of food insecurity predominantly occurs in developing countries and rural areas where populations are generally dependant on locally produced food and have inconsistent access to safe and nutritious food. Mycotoxins are one of the most significant contributors to food and feed insecurity in worldwide, especially in developing countries. Mycotoxins are secondary metabolites of fungi that naturally occur in various foodstuffs and agricultural commodities worldwide (Turner *et al*., 2009). Although hundreds of mycotoxins have been identified, the most widely investigated are aflatoxins (AFs), ochratoxin A (OTA), deoxynivalenol (DON), fumonisins (FUM), zearalenone (ZEA), trichothecenes (TRC) and patulin (PAT) (Miller, 1995; Miraglia and Brera, 2000), due to their frequent occurrence and their severe adverse effects on human and animals, including carcinogenicity, neurotoxicity, immunosuppression, nephrotoxicity, hepatotoxicity, mutagenicity, genotoxicity as well as reproductive and developmental toxicity.

During the past decades, a huge number of scientific papers have demonstrated that the list of raw materials and processed foods actually contaminated by mycotoxins is continuously increasing spanning from peanuts to cereals, spices, coffee, cocoa and dried fruits (D‘ Mello, 2003). Since those crops contaminated by mycotoxins are also used as feed for livestock, these compounds further affect animal growth rates and persist in meat, eggs, milk and dairy products due to their resistance to the decomposition in the digestive systems of animals (Prandini *et al*., 2009; Gizachew *et al*., 2016). Mycotoxin contamination lowers product quality and reduces export values, which may lead to significant economic losses for producing countries. The Food and Agriculture Organization (FAO) of the United Nations has estimated that approximately 25 % of foodstuffs consumed in the world are contaminated by mycotoxins (Duarte *et al*., 2010). Regarding the effects on human health, animal productivity and economy, the prevalence of mycotoxins has led many countries to establish strict regulations for their content in food and feed (Juan *et al*., 2012). The growth of molds and the accumulation of mycotoxins in food and feed are influenced by multiple variables, including water activity (a_w), temperature, pH, atmosphere composition, substrate, interaction among species, and time. During cultivation, factors such as water stress, soil conditions and insect activity will cause the invasion of crops by mycotoxigenic fungi (Wagacha and Muthomi, 2008). During postharvest and storage, fungal growth and mycotoxin contamination increase under favorable conditions (Paterson and Lima, 2010). Additionally, socio-economic factors including unavailability of materials, inadequate marketing and transportation systems and inadequate governmental policy, lack of regulations and legislations can further contribute to favoring mycotoxin contamination.

As toxigenic fungi are ubiquitous, mycotoxins cannot be easily eliminated. Various physical and chemical methods have been recommended to reduce mycotoxins, but only a few have been accepted for practical use. Thus, the prevention of fungal growth and mycotoxin production through strategic interventions represent key steps in risk management. These strategies have been developed to minimize mycotoxin contamination to acceptable levels for consumption. However,

various strategies have not been proven to be sustainable over extended periods and many are not economically and logistically realistic for poorer communities, which typically suffer the highest exposure to mycotoxins. In North African countries, researchers try to establish some strategies to reduce mycotoxin contamination, but studies are rare and not include all mycotoxins and can't be applied for all foodstuffs. To address mycotoxin problems in these countries, intervention strategies should provide improved incentives for management of toxigenic molds and increase public awareness and knowledge through education and extension.

Classification and toxicological aspects of mycotoxins

Aflatoxins

Aflatoxins, are a group of structurally related difurano-coumarin derivatives (Bhatnagar *et al.*, 2003) synthesized via a polyketide pathway by certain species of *Apergillus* section *Flavi* such as *Aspergillus flavus*, *Aspergillus parasiticus*, *Aspergillus parvisclerotegenus*, *Aspergillus minisclerotigenes* and less commonly *Aspergillus nomius* (Kurtzman *et al*., 1987; Pleadin *et al*., 2014). There are more than 20 distinct structurally related aflatoxin compounds, but the four most commonly found are known as aflatoxin B1 (AFB1), aflatoxin B2 (AFB2), aflatoxin G1 (AFG1) and aflatoxin G2 (AFG2) (Tam *et al*., 2006; Hernandez-Martinez and Navarro-Blasco, 2010). Normally, *Aspergillus flavus* produces B aflatoxins only, while *Aspergillus parasiticus* produce both B and G types (Creppy, 2002). These substances are extremely toxic and classified as group 1 carcinogens by the International Agency for Research on Cancer (IARC, 2002). Their detrimental effects on human and animal health include carcinogenic, mutagenic, teratogenic and immunosuppressive effects (Eaton and Gallagher, 1994). Among them, aflatoxin B1 (AFB1) is the most frequent and the most noxious and potent hepatocarcinogen known in mammals. Aflatoxin M1 and M2 (AFM1 and AFM2) are the main monohydroxylated derivatives of AFB1 and AFB2 occurring in milk of mammals whose diet are contaminated with AFB1 and AFB2 and formed in liver by means of cytochrome P450-associated enzymes. Approximately 0.3-6.2% of AFB1 is converted into hydroxylated metabolite AFM1, depending on several factors such as the genotype of the animals, milking practices, seasonal fluctuations and environmental conditions (Unusan, 2006). Wogan and Paglialunga (1974) reported that AFM1 has only 10% of the carcinogenicity of AFB1 in vivo. Since milk is a major commodity for introducing AFs in the human diet, evidence of hazardous human exposure to AFM1 through dairy products has been shown by several studies such as cytotoxicity and genotoxicity (Cole and Cox, 1981). AFM1 is classified as a Group 1 like carcinogenic to humans (IARC, 2002).

Aflatoxins are found in a wide range of food commodities including cereals, figs and nuts. The highest contamination has been found in corn, peanuts and cottonseed (Gourama and Bullerman, 1995). North African populations consume a great amount of cereals and cereal

products, spices, dried fruits and olives. These kinds of foodstuffs are susceptible substrates for growth of aflatoxigenic molds.

Ochratoxin A

Ochratoxins (OTs) are phenylalanyl derivatives of a substituted isocoumarin produced by *Aspergillus ochraceus* and *Penicillium verrucosum* which initially believed to be the main OTs-producing species (Hesseltine *et al*., 1972; Pitt, 1987). Since *Penicillium verrucosum* is considered as more frequently associated with cereals in temperate climates, species of *Aspergillus ochraceus* are commonly found in warm and tropical climate (Pitt and Hocking, 1997). Furthermore, the significance of black Aspergilli as Ochratoxin A (OTA)-producing fungi has changed since the first description of OTA production by *Aspergillus niger* var. *niger* (Abarca *et al*., 1994) and *Aspergillus carbonarius* (Horie, 1995). It is now considered that in food commodities such as grapes, raisins and wine, the OTA contamination is mainly due to *A. carbonarius* and some *A. niger* aggregate species, mainly *A. niger* and *A. tubingensis* (Abarca *et al*., 2001; Perrone *et al*., 2007; 2008). In the ochratoxins group, A-type is the most toxic compound; however B and C ones also exist. OTA has nephrotoxic, carcinogenic, immunotoxic, genotoxic and teratogenic properties of all animal species tested (Pitt *at al.*, 2001). Consequently, the International Agency for Research on Cancer (IARC) has classified OTA in group 2B as a possible carcinogen compound to humans (IARC, 2002). Kidney function is most often affected by OTA, where both acute and chronic exposures cause lesions to form on the organs (Garcia-Cela *et al*., 2012). Indeed, this substance has been associated with Balkan Endemic Nephropathy (BEN) in Southeastern Europe “Balkan” characterized by urinary tumors in humans (Krogh *et al.*, 1977; Pfohl-Leszkowicz *et al.*, 2002; Monaci and Palmisano, 2004). When ingested as a food contaminant, OTA is frequently found in human blood due to its long elimination half-life (about 35 days in serum), as a consequence of its binding to plasma proteins, its enterohepatic circulation and its reabsorption from urine (Studer-Rohr *et al*., 2000). Consequently, OTA is the most detected mycotoxin in human blood all over the world. In North African countries, many authors have shown a high incidence of chronic interstitial nephropathies associated with the consumption of OTA-contaminated food (Abid-Essafi *et al.,* 2003). A preliminary survey reported that the Moroccan population is highly exposed to OTA (Filali *et al.*, 2002). Indeed, 60% of the Moroccan human plasma sampled was positive for OTA with an average concentration of 0.29 ng/mL. In Tunisia, OTA was considered to be a casual agent of a Chronic Interstitial Nephropathy (CIN) (Bacha *et al.*, 1993; Maaroufi *et al.*, 1996; Abid-Essafi *et al.*, 2003). The crops mainly contaminated are cereals and cocoa (Gilmour and Lindblom, 2008; Copetti *et al*., 2010), coffee (Romani *et al*., 2000; De Moraes and Luchese, 2003) as well as grapes (Zinedine and Mañes, 2009; Garcia-Cela *et al*., 2012).

Zearalenone

Zearalenone (ZEA) is a non-steroid estrogen mycotoxin produced by *Fusarium* species including *Fusarium graminearum*, *Fusarium culmorum* (Bennett and Klich, 2003) and *Fusarium*

incarnatum-equiseti species complex (FIESC) (Schroeder *et al*., 1975; Kosiak *et al*., 2005; Leslie and Summerell, 2006; Aoyama *et al*., 2009). ZEA has been shown to competitively bind to estrogen receptors because of the similarity with the sex human hormone. Therefore, it is known to cause estrogenic effects in both humans and animals including infertility, reduced serum testosterone levels and sperm counts, reduced incidence of pregnancy, and change in the progesterone levels (Shier *et al.*, 2001; Sherif *et al*., 2009). ZEA was classified by IARC under group 3 according to the International Agency for Research on Cancer (IARC, 1999). Moreover, this toxin is responsible of hepatotoxic (Conkova *et al.*, 2001) and haematotoxic complications. It causes several alterations of immunological parameters (Abbes *et al.*, 2006). Several studies have demonstrated that ZEA exhibits several genotoxic effects such as the induction of micronuclei, chromosome aberrations, DNA strand breaks and DNA adduct formation (Abbes *et al.*, 2006, 2007). Cereals such as corn, wheat, barley, sorghum and rice are susceptible to be contaminated with ZEA (Manova and Mladenova, 2009). It can also be found in beverages made with contaminated crops (Chen *et al*., 2000).

Fumonisins

Fumonisins (FMs) are a class of mycotoxins mainly synthesized by different species of *Fusarium* section *Liseola* including: *Fusarium verticillioides* and *Fusarium proliferatum* (Chen *et al.*, 1992), but can also reportedelly be produced by *Aspergillus niger* strains. Several fumonisins have been isolated and characterized, but only fumonisin B1 (FB1), fumonisin B2 (FB2) and fumonisin B3 (FB3) are the predominating ones produced in foodstuffs. FB1 has the structure of a diester of propane-1,2,3-tricarboxylic acid. Fumonisins show different toxicological effects in humans and animals. Their natural occurrence in corn was associated with esophageal cancer in many countries (Marasas *et al.*, 1988; Franceschi *et al.*, 1990; Sydenham *et al.*, 1990; Gelderblom *et al.*, 1992; Rheeder *et al.*, 1992; Shephard *et al.*, 2000) and with the promotion of primary liver cancer in certain endemic areas of China (Chu and Li, 1994). Links between exposure to FB1 and esophageal cancer can be found in many epidemiologic studies (Rheeder *et al*., 2002). Accordingly, fumonisins are possible carcinogenic to humans and they are classified in class 2B carcinogens according to the International Agency for Research on Cancer (IARC, 2002). Sherif *et al*. (2009) mentioned that FMs can additionally disrupt sphingolipid metabolism by acting as secondary messengers for growth factors, differentiation factors and cytokines. These toxins may occur in cereals such as corn, wheat, barley and sorghum. Maize is the major food crop affected by FMs, although noteworthy incidence has been found in sorghum and rice (CAST, 2003; Vismer *et al*. 2015).

Trichothecenes

Trichothecenes are a large group of mycotoxins produced mainly by species belonging to different fungal genera, including *Fusarium, Myrothecium, Phomopsis* and *Trichoderma*. All trichothecenes contain a common 12,13-epoxytrichothene skeleton and an olefinic bond with

various side chain substitutions (Bennett and Klich, 2003). According to their chemical structure, they have been classified into four groups: types A-D (WHO, 1990). Trichothecenes primarily cause necrosis and hemorrhage throughout the digestive tube, tract depression of blood regenerative processes in the marrow and spleen, and changes in reproductive organs. Signs of disease include weight loss, reduced feed consumption, vomiting, diarrhea, abortion and death. Immunosuppression may be important in trichothecenes-affected animals (CAST, 1989).

Deoxynivalenol (DON) is the most widespread mycotoxin of the B-trichothecenes group, which are epoxy-sesquiterpenoids (Clear and Patrick, 2000; Eriksen and Pettersson, 2004). Presently, this toxin, also known as vomitoxin, is primarily produced by *Fusarium graminearium* and *Fusarium culmorum* (Desjardins and Proctor, 2001). Its accumulation in human and animal bodies can induce adverse health effects after acute or chronic administration (Pestka, 2010) resulting in teratogenic, neurotoxic, embryotoxic and immunosuppressive effects (Pestka, 2007).

Citrinin

Citrinin (CIT) is a polyketide mycotoxin produced by *Penicillium citrinum*, although it may also be produced by *Penicillium expansum, Penicillium verrucosum* and some species of *Aspergillus* and *Monascus* (Ei-Banna, 1987; Kurata, 1990; Li *et al.*, 2003). Several studies showed that CIT possesses cytotoxic, genotoxic, mutagenic, immunotoxic and teratogenic properties (Wurgler *et al.*, 1991; Liu *et al.*, 2003; Iwahashi, 2007; Bouslimi *et al.*, 2008) and the most important toxic property of this mycotoxin is its nephrotoxic effect (Chagas *et al.*, 1992). Presently, there is no specific legislation for citrinin worldwide. It is difficult to establish widely acceptable limits for this mycotoxin because its instability in foodstuffs.

Patulin

Patulin (PAT) is a polyketide mycotoxin mainly produced by *Penicillium expansum* (Baert *et al*., 2007). Patulin has received different names, such as clavacin, claviformin, expansin, micoinin C and penicidin (Ciegler *et al*., 1971). In view of its antimicrobial properties, this mycotoxin has been used for the treatment of colds and skin infections (Ciegler *et al*., 1971; Ciegler, 1977). However, during the 1960s, it was shown that this substance is also toxic. Following these revelations, patulin was considered a true mycotoxin (Bennet and Klich, 2003). Acute symptoms of PAT exposure can include agitation, convulsions, edema, ulceration, intestinal inflammation and vomiting (Speijers, 2004). The chronic health effects of patulin include genotoxicity, immunotoxicity, embryotoxicity and neurotoxicity (Wouters and Speijers, 1996). However, no adequate evidence exists for carcinogenicity in experimental animals and humans. It is not classifiable as to its carcinogenicity to humans, and it is included in Group 3 of the International Agency for Research on Cancer (IARC, 1993). Apples, pears, cherries and other fruits can be infested with *Penicillium expansum* responsible for a pathology called "blue mold". Although *Penicillium expansum* is the most important producer of patulin, other species such as *Aspergillus clavatus*, *Aspergillus giganteus* and *Aspergillus terreus* are also able to produce this mycotoxin (Pier and Richard, 1992). It is commonly

found in unfermented apple juice. This substance is not resistant to the fermentation process and is efficiently metabolized by yeast during the preparation of the cider and its derivatives (Moss and Long, 2002).

Mycotoxin and toxigenic fungi occurrence in food commodities in North African countries

Cereals

Cereals are the most important source of food in the world either through direct human consumption or indirectly through their use in feeding livestock. Latest FAO forecasts indicate that global cereal production in 2011 increased by 3.3% from 2010 to 2313 million tons (FAO, 2011). Obviously, this high production must comply with the safety standards of foodstuffs for humans and animals considering the economic and health impact of this type of food. Post harvest losses in food grains in developing countries have been estimated conservatively during the 1980s as 10-15% by the FAO's Special Action Program for the Prevention of Food Losses (FAO, 2004b). One of the main agents that cause these significant losses in cereals is fungi. Cereal plants may be contaminated by mycotoxigenic fungal strains during anthesis (Beyer *et al*., 2007) that continue their proliferation during harvest and storage under favorable conditions (Glenn, 2007). In addition, these fungi are capable of producing not only losses in the organoleptic quality of the grain but accumulating mycotoxins in cereals that can cause health problems to humans and animals (Thiel *et al*., 1992; Chu and Li, 1994). Devegowda *et al*. (1998) reported that about 25% of cereals consumed worldwide are contaminated with mycotoxins. The European Commission has set maximum permitted levels in processed cereal products for direct human consumption: 2 ng/g for AFB1 and 4 ng/g for the sum of AFB1, AFB2, AFG1 and AFG2; 3 ng/g for OTA and 75 ng/g for ZEA (table 1) (European Commission, 2006a,b; 2010).

North African and Tunisian populations consume cereals such as wheat, barley, corn and sorghum in form of couscous, pasta, bread, cookies, cakes and malted beverages. Moreover, cereals contribute to approximately 12% output and Tunisian households spend around 25% of their food expenditures on cereals. Tunisia and other North African countries, sourrounded by the Mediterranean Sea, are characterized by a hot and humid climate, which probably favors growth of molds.

Wheat is a primary foodstuff in North African countries. It is commonly consumed in form of bread, pasta, couscous and other processed products. Durum wheat is the most widely grown cereal in Tunisia covering about 700 000 ha each year, mainly located in the north of the country (Bensassi *et al*., 2010). Generally, wheat production systems are vulnerable to degradation by toxigenic fungal species. In 2004, *Fusarium* Head Blight (FHB) was observed on durum wheat in sub-humid and higher semi-arid region of Northern Tunisia. This disease is caused by the development of a complex of two genera of pathogenic fungi under warm and humid conditions: *Fusarium* and *Microdochium* (Simpson *et al.*, 2001). The most common *Fusarium* species

associated with the disease are *Fusarium graminearium*, *Fusarium culmorum*, *Fusarium avenaceum* and *Fusarium poae* (Edwards *et al.*, 2001). Gargouri Kammoun *et al.* (2009) showed that the most common species isolated from infested wheat spikes from the Northern area of Tunisia was *Microdochium nivale* var *nivale* (63.5%), followed by *Fusarium culmorum* (26%), *Fusarium pseudograminearum* (9%) and *Fusarium avenaceum* (1.5%). In another investigation, *Fusarium culmorum*, considered highly pathogenic, was the most abundant representing 36.6% of all single spore culture samples isolated from durum wheat samples collected from Northern Tunisia area during 2004 and 2007 (Fakhfakh *et al.*, 2011). The disease has become a serious problem causing significant reduction of grain yield and quality in most of durum wheat production areas **(**Olivier *et al.*, 2008). The most serious effect of FHB is the grain contamination with mycotoxins produced by *Fusarium* species, especially DON, and the potential health hazard for humans and animals (Placinta *et al.*, 1999). Bensassi *et al.* (2010) showed that 83% of durum wheat samples cultured in Tunisia were contaminated with DON with averages ranging from 12.8 ± 5% to 30.5 ± 13.3% µg/g exceeding the maximum permitted limit of 1.75 µg/g set by the European Commission in wheat. In Morocco, 41.17% of wheat samples were contaminated by DON at levels below the limit proposed by EU legislation Hajjaji *et al.* (2006). Recently, Ennouari *et al.* (2013) showed that Moroccan wheat contained DON with an incidence of 11.1%. Other *Fusarium* toxins such as ZEA, T-2 and fusarin C were detected in Mediterranean and North African food due to the contamination of samples by *Fusarium moniliforme* and *Fusarium oxysporum* (El-Maghraby *et al*., 1995; Aziz *et al*., 1997). Several studies showed that ZEA was detected in wheat from Egypt (Abd Alla, 1997; Aziz *et al*., 1997) and Tunisia (Zaied *et al.,* 2012b). Ochratoxin A was also detected in wheat samples from Algeria, Tunisia, Morocco (Hajjaji *et al.,* 2006; Zinedine *et al.,* 2006; Riba *et al.*, 2008; Ghali *et al.*, 2009; Zaied *et al.,* 2009). Studies on the mycobiota of wheat grains originated from North African countries revealed that *Aspergillus*, *Penicillium*, *Alternaria*, *Rhizopus* and *Fusarium* were predominant (Hajjaji *el al.,* 2006; Riba *et al.*, 2008; Riba *et al,.* 2010; Embaby *et al.,* 2012). According to Ghali *et al.* (2010), AFs were detected in 28.6% of cereal samples such as wheat. In Algeria, the frequency of AFB1 contamination in pre-harvest and stored wheat was 56.6% and the highest level of AFB1 was found in a wheat sample stored for 12 months (Riba *et al.*, 2010). In one study, Tunisian wheat was surveyed for the presence of CIT. Analyzed samples were contaminated with an incidence of 50% (Zaied *et al.*, 2012a).

In Egypt, corn is an important product for human and animal consumption and for the industrial processing for starch, glucose, and syrup obtention. Corn flour is also used for stable bread (balady). In order to lower the price, corn and corn flour was detected as partial substitute for wheat flour in balady and tortilla production (Hussein *et al*., 2013). Corn was proved to be a good substrate for the growth of *Aspergillus*, *Penicillium* and *Fusarium.* Madbouly *et al.* (2012) reported that the mycobiota of maize samples was represented by *Aspergillus flavus* and *Aspergillus niger* with an incidence of 33% and 40%, respectively. According to Ghali *et al.* (2010), AFs were

detected in 28.6% of cereal samples including maize and about 15.5% of cereal samples had AFB1 levels higher than the European maximum limit for AFB1 in cereals intended for human consumption (2 ng/g) while 9.4% of them exceeded the European maximum limit for AFs (4 ng/g). Total aflatoxins were detected in maize purchased from retail market in Cairo (Egypt) (Madbouly *et al.*, 2012). Fadl Allah (1998) showed that the majority of *F. moniliforme* isolates from Egyptian corn produced FB1 and FB2. In Egypt, T-2 was detected in yellow corn samples and in white corn and popcorn samples (Abd Alla El-Sayed *et al.*, 2003). Several cereal samples were reported to contain ZEA in Egypt, especially wheat, corn and rice with levels up to 45 mg/kg (Abd Alla, 1997). The incidence of contamination of aflatoxins in corn flour commercialized in the retail markets of Rabat (Morocco) was 80% with a maximum value of 11.2µg/kg (Zinedine, Juan, Soriano *et al.*, 2007).

Sorghum (Sorghum bicolor) is the fifth most important cereal crop in the world, after wheat, rice, maize and barley and the second most important crop (after maize) in sub-Saharan Africa (FAO, 1994). It constitutes the main grain food for over 750 million people who live in semi-arid tropics of Africa, Asia and Latin America (Codex Alimentarius Commission, 2012). It is mainly cultivated in semi-arid and subtropical regions because of its resistance to harsh weather conditions and its efficient use of water makes it the crop of choice to boost food security in drought stricken regions. Sorghum grains are used as feedstock for poultry, pigs and cattle feed, but also for human beings as staple foods in some African and Asian countries (Veiga, 1986). However, sorghum grains is susceptible to colonization by several toxigenic fungi during cultivation as well as after harvest (Waliyar *et al*., 2007), which constitutes a major constraint to an increase in sorghum production worldwide. Several species of *Aspergillus*, *Alternaria*, *Fusarium*, *Cladosporium*, *Curvularia* and *Penicillium* are among the prevalent grain mold pathogens in sorghum (Bandopadyay *et al*., 2000; Lahouar *et al.*, 2015). Toxigenic species of *Aspergillus flavus*, *Aspergillus niger* aggregates and *Fusarium incarnatum* has been associated with sorghum seeds in Tunisia (Lahouar *et al*., 2015). Therefore, sorghum may contain zearalenone, fumonisins, aflatoxins and ochratoxin A. However, there is limited information about mycotoxins in sorghum. In Tunisia, preliminary surveys of mycotoxins showed relatively high levels of AFs contamination in sorghum (Boutrif *et al*., 1977a). Since 1977 several studies have confirmed mycotoxin contamination in Tunisian sorghum (Ghali *et al*., 2008; Ghali *et al*., 2010; Serrano *et al*., 2012; Oueslati *et al*., 2012; Oueslati *et al*., 2014).

Fusarium was the most dominant genus in Egyptian rice (El-Maghraby, 1996) of which *F. tricinctum* and *F. oxysporum* were proved to be producers of T-2 toxin and ZEA. Ghali *et al*. (2010) reported that no rice samples were contaminated with aflatoxins. However, Total aflatoxins were detected in rice purchased from retail market in Cairo (Egypt) (Madbouly *et al.*, 2012).

Milk

The occurrence of AFM1 in pasteurized milk samples was surveyed in Morocco. The incidence of AFM1 was very high (88.8%) and 7.4% of total samples exceeded the maximum level

of 0.05 µg/kg set by both Moroccan and European regulations for AFM1 in liquid milk (Table 1 and 2) (Zinedine, Gonzales-Osnaya, Soriano *et al.*, 2007). These results indicate that feed for cows in Morocco were contaminated with AFB1. The contamination of dairy cattle and cow's plasma with AFB1 and the contamination of raw milk by AFM1 have been studied in Tunisia (Abbes, Ben Salah-Abbes, Bouraoui *et al*., 2012). Results revealed the presence of AFB1 in 84.4% of the feed samples, and in 39.2% of the plasma-examined samples. AFM1 was detected in 60.7% of the cow raw milk samples examined.

Olives

Postharvest storage conditions could result in the production of olive oil with a high risk of contamination by mycotoxins (Tantaoui-Elaraki *et al.*, 1983a). Several studies have reported that olives can be a substrate for mold growth. Strains of *Penicillium*, *Aspergillus*, *Alternaria*, *Rhizopus* and *Geotrichum* were detected in Morocan olives (Gourama and Bullerman, 1988; Roussos *et al.*, 2006). Some species, in particular, *Aspergillus flavus* and *Aspergillus ochraceus* were able to produce aflatoxin B1 and ochratoxin A, respectively, in olives. The development of fungi on olives is responsible for the reduction of nutritional quality of olive because they can disturb the synthesis of the fatty acids. The oil resulting from such olives contains small quantities of such mycotoxins (Tantaoui-Elaraki *et al.*, 1983a). OTA was found in Moroccan olive oil (Tantaoui-Elaraki *et al.*, 1983b; Belaiche, 2001). Moreover, the olive cake resulting from such olives could present a danger for animals because of the preferential concentration of mycotoxins in oil cakes (Tantaoui-Elaraki *et al.*, 1983a). Maaroufi *et al.* (1995) reported the contamination of one sample of black olives from Tunisia with a high level of OTA (46.83µg/kg). A survey of the contamination of black olives commercialized in Morocco reported that OTA was detected in 36% of analyzed samples with concentrations ranging from 0.62 to 4.8µg/kg (Zinedine *et al.*, 2004). El Adlouni *et al.* (2006) showed that there were more OTA contaminated samples from retailers than from supermarkets. This is probably due to the storage conditions, which may be relatively better in supermarkets. The same researchers showed that 80% of olive samples contained also CIT.

Spices

Spices are largely used in North African countries for flavoring foods. Few countries around the world have effectively established regulations for mycotoxins in spices. For instance, the maximum tolerable limit for AFs allowed in some spices such as chili, paprika, black and white pepper, ginger and curcuma, in EU member states have been set at 10µg/kg for total AFs and 5 µg/kg for AFB1 (table 1) (European Commission, 2002). El Mahgubi *el al.* (2013) observed a widespread contamination of paprika, cumin and pepper from Egypt by *Aspergilli* section *Flavi* with 57% of isolates able to produce AFB1, AFB2 and AFG1. In Tunisia, Ghali *et al.* (2010) reported that about 69.2% of spice samples contained aflatoxins with a high occurrence of AFB1. In Morocco, red paprika was highly contaminated with AFB1 but also cumin, ginger and black pepper contained AFB1 (Zinedine *et al.*, 2006). El-Kady *et al*. (1995) reported that aflatoxins were detected in anise,

black pepper, caraway, black cumin, fennel, peppermint, coriander and marjoram, and citrinin in black cumin from Egypt. OTA did occur also in spices. The contamination frequency of OTA in spices commercialized in Tunisia such as, red pepper, cumin and black pepper was 57.1% (Ghali *et al.*, 2008). More recently, OTA was found in 30% of total analyzed samples (Ghali *et al.*, 2009). The contamination frequency of ZEA in red pepper, cumin and black pepper was 2.8% of samples from retail market in Tunisia (Ghali *et al.*, 2008).

Beverages

Many studies have shown that ochratoxin A is frequently present in wine and grape juice **(**Zimmerli and Dick, 1996). In fact, wine is the second source of OTA intake after cereals (Codex Alimentarius Commission, 1999). Furthermore, OTA is a restrictive factor for exporting viticultural products. Since January 2005 and according to the "Organisation Internationale de la Vigne et du Vin (OIV)" proposal, the European Union authorities have set the acceptable limit for OTA in wine at 2 µg/l (table 1) (European Commission, 2006a). There is a great concern about OTA in the Mediterranean region because of the climatic conditions favorable for invasion of grapes by black *Aspergilli*, in particular *Aspergillus carbonarius* (Battilani *et al.*, 2003; Bellí *et al.*, 2004; Bejaoui *et al.*, 2006). *Aspergillus* and *Penicillium* species are reported as the main producers of ochratoxin A on grape (Pitt, 1987; Zimmerli and Dick, 1996). In the Tunisian vineyard, the main disease observed on grapes so far is the grey rot caused by *Botrytis cinera* (Chebil *et al.*, 2004). However, in the last four years, the presence of *Aspergillus* species is significantly increasing on both table and wine grapes, especially at the maturation stage. *Aspergillus* species belonging to the section *Nigri* can cause considerable damage on the yield and the quality of the harvest. Studies showed that Tunisian vineyards were contaminated essentially with *Aspergillus* spp., *Botrytis cinerea* and *Alternaria* spp. (Lasram *et al.,* 2007, Melki Ben fredj *et al.,* 2007). Among the potential OTA-producing fungi, only black Aspergilli (*Aspergillus* section *Nigri*) were the most abundant mycobiota isolated from Tunisian grapes. The number of *A. carbonarius* isolates increased from early veraison to the maturity. Of the *A. carbonarius* isolates, 94% produced OTA. However, only 3% *A. niger* aggregates isolates were ochratoxigenic (Lasram *et al*., 2007). Grapes and grape products are widely consumed in Tunisia as fresh fruit, raisins and wine, and 30% of the Tunisian grape products are exported. To study the occurrence of OTA in Tunisia, grapes purchased during the 2004 season from the northern area were analyzed, for the first time, for their OTA content. OTA was found in 37% of musts obtained from grape samples at levels varying between 0.59 and 2.57µg/L (Lasram *et al.*, 2007). More recently, another survey involving four viticultural regions of Tunisia was performed. Results showed that 58% of grape samples contained detectable levels of OTA, between 0.05 and 5.85µg/L. In another report, Melki Ben Fredj showed that the concentration of OTA in Tunisian grape samples was between 1.1 and 4.3µg/L (Melki Ben Fredj *et al.*, 2007). According to Lasram *et al.* (2013), OTA levels in Tunisian wines and beers were below the European regulatory limit and there were no toxicological risks for Tunisian consumers. Filali *et al.* (2001) showed that the red wines from

Morocco were contaminated with OTA. In one study, Zaied *et al*. (2013) showed that apple based food such as apple and mixed juice marketed in Tunisia were contaminated with patulin and 18% of the total juice samples and 28% of the baby food samples exceeded the tolerable limit recommended by the European Commission, which are respectively 50 and 10 µg/l.

Dried fruits

North African population consumes huge amounts of dried fruits directly or as ingredients in special foods. Traditional techniques of transformation and conservation of dried fruits used in North African countries consist in direct exposition of fruit to a maximum sunning. During the process of fruits drying, the sugar is concentrated as the moisture content decreases resulting in an almost selective medium for xerotolerant molds such as *Aspergillus* section *Nigri* species. According to Pitt and Hocking (1997), *A. flavus* and *A. niger* were reported as being the most common species in dried figs which was explained by their high sugar content. Among black Aspergilli, *A. carbonarius* was the OTA producer species isolated more frequently. The mycobiota of dried fruits such as apricots, figs, raisins and plums from Egypt was composed of *Penicillium chrysogenum*, *Aspergillus niger*, *Cladosporium cladosporioides*, *Penicillium aurantiogriseum*, *Aspergillus fumigatus*, *Aspergillus flavus*, *Alternaria tenuissima* and *Pleospora herbarum* (Zohri and Abdel-Gawad,1993). AFB1 and AFG1 were detected in dried figs from Morocco (Juan *et al.*, 2008). OTA was detected in dried figs, dried raisins, apricots and plum (Zohri and Abdel-Gawad, 1993; Zinedine, Soriano, Juan *et al.,* 2007). The European Commission has set maximum limits for AFB1, AFs and OTA in dried fruits and nuts intended for direct human consumption (table 1) (European Commission, 2006a,b; 2010).

Nuts

Nuts are a good substrate for mold infection and production of mycotoxins. Preliminary reports have shown relatively high aflatoxins levels in Aleppo pine nuts from Tunisia (Boutrif *et al.*, 1977a,b; Said *et al.*, 1999). Fername *et al.* (2010) have studied the mycobiota of 31 pistachio samples collected from retail outlets from different regions of Algeria. The most frequently found fungi were *Penicillium* spp. (38%), *Aspergillus* section *Nigri* (30%) and *Aspergillus* section *Flavi* (22%). A total of 56.5% of *A. flavus* isolates were able to produce AFB1 and AFB2, whereas OTA production capacity was detected in 33.3% of the *A.* section *Nigri* biseriate. However, only two samples contained aflatoxins (0.4 and 0.7 µg/kg) and only one sample showed ochratoxin A contamination (170 µg/kg) (Fernane *et al.,* 2010). Juan *et al.* (2008) showed the presence of aflatoxins in nuts commercialized in Rabat especially in walnuts and pistachios which were found contaminated with high levels of AFB1 ranging from 0.56 to 2500µg/kg and from 0.04 to 1430µg/kg, respectively. Zinedine, Soriano, Juan *et al.* (2007) found that the incidence of OTA in walnuts and peanuts commercialized in Morocco was 35% and 25% respectively, while pistachio samples were free of OTA. In Tunisia, Ghali *et al.* (2010) showed that aflatoxin levels in pistachios were around 4.9 ng/g (45.7% of samples were contaminated) and around 5.1 ng/g in groundnuts (42.4% of

samples were contaminated). Abdel-Hafez and Saber (1993) have studied fungal colonization of walnut and hazelnut seeds commercialized in Egypt. The mycobiota was composed by species from *Aspergillus* (*Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*), *Penicillium* (*Penicillium citrinum*), *Eurotium*, *Fusarium* (*Fusarium equiseti*, *Fusarium moniliforme*), *Cladosporium* genera but only AFs and ZEA were detected in all samples. The major mycotoxins found in peanuts commercialized in Egypt were aflatoxins, OTA, DON and ZEA. Samples are predominantly contaminated with *Aspergillus niger*, *Aspergillus flavus*, *Aspergillus ficuum*, *Penicillium citrinum* and *Fusarium oxysporum* (Youssef *et al*., 2008; Sultan and Magan, 2010).

Environmental conditions modulating mycotoxin accumulation

Over the past decades, the world has experienced a remarkable climate change characterized by a trend of warming. Scientists have described how plausible changes in temperature, precipitation, drought and CO_2 increase pose a significant risk to the food availability and quality (Miraglia *et al*., 2009). Longer and more severe droughts periods are projected for West Africa and Southern Europe, while periods of drought have been shorter in Central Europe and America (IPCC, 2012). Drought is a major stressor for plants. It affects their natural immunity against pathogens including mycotoxigenic fungi. Precipitation is also a key environmental factor in the development of mycotoxins. Heavy rains during anthesis (flowering) of the plants are associated with the dispersion of *Fusarium* in corn ears leading to a higher production of mycotoxins (Parry *et al*., 1995). Finally, unseasonable rains at the time of harvest causes the invasion of dry crops by mold. Therefore, mycobiota (fungal flora) and the nature of mycotoxins contaminating any commodity vary from year to year depending on climatic conditions. Thus, new strategies recently developed to monitor and predict mycotoxin contamination either in specific foods or in geographic areas can be very useful in the future. The modeling of fungal growth and the production of mycotoxins under the influence of ecological factors is an essential step in understanding the physiology of these microorganisms, predicting final levels of contamination by fungi or mycotoxins and determining storage conditions. Predictive mycology is a very useful tool for decision-making and the implementation of relevant solutions to prevent risks to human and animal health. In this regard, many kinetic models have been developed and used to model the growth of toxigenic molds in various food substrates. The Baranyi model was applied to identify the growth rate of many *Aspergillus* and *Penicillium* species, while the linear model was used to predict *Fusarium* species growth. In North African countries, mathematical modeling studies of the influence of ecological factors on fungal growth and mycotoxin accumulation are rare. The growth of molds and the accumulation of mycotoxins in food and feedstuff are influenced by multiple variables, such as water activity (a_w), temperature, pH, atmosphere composition, substrate, interaction among species, and time (Samson *et al.*, 2000; Astoreca *et al.*, 2014). Temperature and water activity (a_w) are primary determining factors that modulate mycilial growth and mycotoxin production and were the most

studied ecological factors in worldwide. In general, *Fusarium* growth is more common in temperate weathers at temperatures ranging from 26 to 28 °C and water activity >0.88, while *Aspergillus* (*A. flavus*) grows under warm temperatures. Thus, optimal temperature for aflatoxin production vary from 24 to 30 °C depending to the strain and the substrate composition (Klich, 2007). Recent studies evaluating the effect of temperature and a_w on AFs production by *A. flavus* in rice showed that the highest AF concentrations were observed under a_w ranges of 0.9- 0.92 a_w (Mousa *et al.*, 2013). Lahouar *et al*. (2016) showed that fungal growth and aflatoxin production were optimal at 0.99 a_w and 37 °C for *Aspergillus flavus* strains from Tunisia which are cultivated in sorghum seeds. In another study, Lahouar *et al*. (2017) reported that the growth rate of the Tunisian *Aspergillus tubingensis* strains was optimal at 37 °C and 0.99 a_w but OTA production was optimal at 0.97 a_w and 37 °C. It seems that the Tunisian strains are adapted to the hot and humid climate of the country. In another study, Lasram *et al.* (2016) showed that optimal conditions for OTA and AFB1 production were 0.98 a_w and 20 °C and 0.95 - 0.98 a_w and 28 °C by *A. niger* and *A. flavus*, respectively when cultivated in barley meal extract agar. However, in this study, temperatures over 30 °C haven't been investigated. Kinetic models were also used to evaluate the influence of a_w and temperature on the OTA production by Tunisian *A. carbonarius* cultivated in synthethic grape medium. Thus, Marin *et al*. (2006) showed that the OTA production was higher at 20 °C. In another study, Lasram *et al.* (2010) showed that optimal a_w level was 0.99 for both growth and OTA production by ochratoxigenic *A. carbonarius* isolated from Tunisian grapes. About *Fusarium* species, we know only one study carried out with toxigenic *F. incarnatum* strains isolated from Tunisian sorghum where the researchers showed that growth was optimal at 25 °C and 0.99 aw but ZEA accumulation varied from one isolate to another and it seems to be stimulated by stress temperature (15 °C) (Lahouar *et al.*, 2017).

Legislations and mycotoxin regulations in worldwide and North African countries

As mycotoxins can never completely removed from the food supply, many countries have defined maximum levels in foods that are unlikely to be of health concern and are reasonable to achieve by following good practices of agriculture, manufacturing and storage. Various factors may influence the establishment of mycotoxin limits and regulations including: availability of toxicological data, availability of data on the occurrence of mycotoxins in various commodities, legislation in other countries with which trade contacts exist and need for sufficient food supply (Van Egmond *et al*., 2007). Regulations in individual countries usually depend on the ultimate use, with the strictest limits defined for human consumption, and export products and the lowest for individual uses. Indeed, safe limits of AFs for human consumption range 4-20 µg/kg. The EU has set the strictest standards, such that any products for direct human consumption can only be marketed with concentrations of AFB1 and total AFs not higher than 2 µg/kg and 4 µg/kg, respectively (European Commission, 2007; European Commission, 2010). The European Union's (EU) integrated strategy aims to ensure

a high level of food safety, animal health and plant disease control in the European Union (EU) countries through measures coherent and adequate supervision, while maintaining high production and ensuring the functioning of the internal market. The European Food Safety Authority (EFSA) is the European Union body responsible for assessing the safety risks of food and feed. Risk assessment is done at two levels: European and International where the evaluation is carried out by JECFA (Joint Expert Commitee of Food and Additives), which also analyzes the toxicity of mycotoxins and develops recommendations at the Codex Alimentarius level (Van Egmond *et al*., 2007). European legislation and Codex Alimentarus standards are not necessarily identical. In the case of mycotoxins, European legislation is often more severe than Codex standards. EU regulations and recommendations related to different foodstuffs are summarized in Table 1. Comparing the worldwide situation in 1995 and 2002, apparently in 2002 more countries were known to have regulations for more mycotoxins in more commodities and products. Table 2 shows the limits for mycotoxins in several foodstuffs and commodities in North African countries. In Africa, fifteen countries are known to have specific mycotoxin regulations. Most of the existing mycotoxins regulations in Africa concern the aflatoxins. Tunisia has established the maximum tolerable level of AFs in various foodstuffs at 2ng/g (INORPI, 1983). In Egypt, the tolerable limit was set at 5 µg/kg in cereals, oil seeds and peanuts and at 10 µg/kg in maize for AFB1 and at 10 and 20 for AFs respectively (Mazumdar and Sasmal, 2001). The maximum level for AFB1 in Algeria is 10 µg/kg (FAO, 2004a). In Morocco, mycotoxins regulations were prepared by the interdepartmental committee for food control and the repression of frauds (CIPCARF). These regulations concern limits of AFB1, OTA and ZEA in cereals intended for human consumption, the limit of AFM1 in milk and dairy products for adults and children and the maximum limit of patulin in fruits and juices. Legal limits for AFB1 in animal feeds were also established. Morocco seemed to have the most detailed mycotoxin regulation (FAO, 2004a).

Stratigies to reduce mycotoxin contamination in food commoditties

Possible origins of fungal infection and mycotoxin contamination are multiple. Thus, strategies to prevent or minimize fungal contamination should be applied throughout the food chain. Three intervention steps were identified. The first is to prevent fungus infestation. The second step is during the invasion of plants by fungi and the production of mycotoxins. The third is initiated when agricultural products have been identified as contaminated by fungi and their mycotoxins. The most effective prevention steps are those carried out before the fungal infestation and before mycotoxin production occur on plant. Several agricultural practices can minimize the contamination of crops by fungi without completely eradicating them, including: crop rotation, tillage, planting date, chemical and biological control of toxigenic fungi especially *Fusarium*, insect and weed control (Jouany, 2007). The control of mycotoxin contamination can also occur during and after harvest. These practices include the elimination of infested crops and grains, the control of temperature and

humidity level after harvest and during storage, thermal treatment, Gamma irradiation, chemical treatment of infested grains, biological decontamination of mycotoxins using bacteria, yeasts or fungi and the use of adsorbents (Jouany, 2007).

In North African countries, researchers tried to find solutions and to develop strategies to prevent mycotoxin contamination. In one study, Abbès *et al.* (2008) demonstrated that the Tunisian montmorillonite, a clay mineral, was safe and successful in the prevention of aflatoxin toxicity and cytotoxicity. Recently, the Tunisian montmorillonite clay, the living *Lacotobacillus plantarum* MON03 cells and their composite were tested for the ability to accumulate zearalenone (ZEA) from liquid medium (Abbes, Ben Salah-Abbes, Sharafi *et al.*, 2012). Results indicated a high capacity of absorbing ZEA by both montmorillonite (87.2%) and *L. plantarum* (78%), however, the combination between the montmorillonite clay and the lactic bacteria showed the higher ability to remove ZEA (94.2%). In vivo, both montmorillonite clay, *L. plantarum* and their composite showed a high capacity to counteracting ZEA-immunotoxicity in Balb/c mice Abbes, Ben Salah-Abbes, Sharafi *et al.*, 2012). *Lactobacillus paracasei* BEJ01 (LP) isolated from Tunisian artisanal butter was found to display significant binding ability to ZEA in phosphate-buffered saline (96.6%) within 24 h of incubation. In vivo, mice receiving ZEA- *L. paracasei* co-treatment haven't displayed adverse immunotoxic effects as compared to Balb/c mice exposed to ZEA only (Abbes *et al*., 2013). Zinedine *et al.* (2005) showed that *Lactobacillus* strains are able to remove aflatoxin B1 and suggest that lactic acid bacteria isolated from Moroccan traditional sourdough ferments can be exploited as an approach of detoxification of aflatoxins from foods. Soil microorganisms can also be used to reduce the level of contamination of mycotoxins. Thus, strains of mycelial actinobacteria isolated from the Saharan soils of Algeria were tested in vitro for the efficacy to reduce AFB1 content. Among the tested strains, two strains belonging to the genus *Streptomyces* and one to the genus *Saccharothrix* showed the highest ability to reduce the level of aflatoxin B1 (Lahoum *et al*., 2017). Therefore, limiting the toxicity of mycotoxins by using clays and bacteria to adsorb or degrade these toxins may represent an alternative strategy for decreasing food and feed contamination. These include adding clay or bacteria to feeding livestock to mitigate the adverse effects of mycotoxins on animals, reducing the level of contamination of food products of animal origin (milk, for example) by mycotoxins and subsequently reduce economic losses.

To ensure food safety in cereal products, the SMID (Société des Minoteries et des Industries Diverses), a wheat grinding company of the region of Sahel in Tunisia, has implemented during 2005 and 2006 the ISO 22000 system in order to monitor the chemical, physical and microbial hazards including fungi invasion and mycotoxin production (Gaaloul *et al*., 2011). Finally, it can be concluded that all these studies are not sufficient to minimize the contamination of agricultural products by mycotoxins. It is very interesting to sensiblize farmers and to inform them about the importance of certain good agricultural practices such as crop rotation, deep tillage, avoiding irrigation during flowering and control moisture after harvest.

Conclusion

North African population is exposed to the risk of mycotoxins due to consumption of contaminated food. Toxigenic molds were frequently detected in several commodities known to be favorable substrates for mycotoxin production. The presence of toxigenic fungi and their mycotoxins was explained by the Mediterranean climate characterized with high temperature and humidity. Reducing fungal growth is a primordial step to minimize contamination levels by establishing good agricultural practices, good manufacturing practices and the hazard analysis and critical control point system.

Acknowledgements

The authors are grateful to the European Union (MYCORED KBBE-2007-2-5-05 project) and Tunisian government for the financial support.

References

Abarca, M.L., Bragulat, M.R., Castella, G. and Cabanes, F.J. 1994. Ochratoxin A production by strains of *Aspergillus niger* var-*niger*. Applied and Environmental Microbiology 60: 2650-2652.

Abarca, M. L., Accensi, F., Bragulat, M. R. and Cabañes, F.J. 2001. Current importance of ochratoxin A-producing *Aspergillus* spp. Journal of Food Protection 64: 903-906.

Abbes, S., Ben Salah-Abbes, J., Ouanes, Z., Houas, Z., Othman, O., Bacha, H., Abdel-Wahed, M.A. and Oueslati, R. 2006. Preventive role of phyllosilicate clay on the immunological and biochemical toxicity of zearalenone in Balb/c mice. International Immunopharmacology 6: 1251-1258.

Abbes, S., Ouanes, Z., Ben Salah-Abbes, J., Abdel-Wahhab, M., Oueslati, R. and Bacha, H. 2007. Preventive role of aluminosilicate clay against induction of micronuclei and chromosome aberrations in bone-marrow cells of Balb/c mice treated with zearalenone. Mutation Research 631: 85-92.

Abbes, S., Ben Salah-Abbès, J., Hetta, M. M., Ibrahim, M., Abdel-Wahhab, M. A., Bacha, H. and Oueslati, R. 2008. Efficacy of Tunisian montmorillonite for in vitro aflatoxin binding and in vivo amelioration of physiological alterations. Applied Clay Science 42: 151-157.

Abbes, S., Ben Salah-Abbes, J., Bouraoui, Y., Oueslati, S., and Oueslati, R. 2012. Natural occurrence of aflatoxins (B1 and M1) in feed, plasma and raw milk of lactating dairy cows in Beja, Tunisia, using ELISA. Food Additives and Contaminants: Part B 5(1): 11-15

Abbes, S., Ben Salah-Abbes, J., Sharafi, H., Akbari Noghabi, K., Oueslati, R. 2012. Interaction of *Lactobacillus plantarum* MON03 with Tunisian Montmorillonite clay and ability of the composite to immobilize Zearalenone *in vitr*o and counteract immunotoxicity *in vivo.* Immunopharmacology and Immunotoxicology 34(6): 944-950.

Abbes, S., Ben Salah-Abbes, J., Sharafi, H., Oueslati, R., Akbari Noghabi, K. 2013. Lactobacillus paracasei BEJ01 prevents immunotoxic effects during chronic zearalenone exposure in Balb/c mice. Immunopharmacol Immunotoxicol 35(3): 341-348.

Abd Alla El-Sayed, A.M, Aly Soher, E. and Sahab, A.F. 2003. Occurrence of certain mycotoxins in corn and corn-based products and thermostability of fumonisin B1 during processing. Nahrung/Food 47: 222-225.

Abd Alla, E.S. 1997. Zearalenone: toxigenic fungi and chemical decontamination in Egyptian cereals. Nahrung 41: 362-365.

Abdel-Hafez, A.I. and Saber, S.M. 1993. Mycoflora and mycotoxin of hazelnut (*Corylus avellana* L.) and walnut (*Juglans regia* L.) seeds in Egypt. Zentralblatt fur Mikrobiologie 148: 137-147.

Abid-Essafi, S., Hassen, W., Achour, A., Skhiri, H., Maaroufi, K., Ellouz, F., Creppy and E., Bacha, H. 2003. Ochratoxin A and human chronic nephropathy in Tunisia: is the situation endemic? Human and Experimental Toxicologie 22: 77-84.

Aoyama, K., Ishikuro, E., Nishiwaki, M. and Ichinoe, M. 2009. Zearalenone contamination and the causative fungi in sorghum. Journal of the Food Hygienic Society of Japan (Shokuhin Eiseigaku Zasshi). 50 (2): 47-51.

Astoreca, A., Vaamonde, G., Dalcero, A., Marin, S. and Ramos, A.J. 2014. Abiotic factors and their interactions influence on the co-production of aflatoxin B1 and cyclopiazonic acid by *Aspergillus flavus* isolated from corn. Food Microbiology. 38: 276-283.

Aziz, N.H., Attia, E.S. and Farag, S.A. 1997. Effect of gamma-irradiation on the natural occurrence of *Fusarium* mycotoxins in wheat, flour and bread. Die Nahrung. 41: 34-37.

Bacha, H. Maaroufi, K., Achour, A., Hammami, M., Ellouz, F. and Creppy, E. E. 1993. Ochratoxines et Ochratoxicoses humaine en Tunisie. In: INSERM/John Libbey EUROTEXT (Ed.)*, Human ochratoxicosis and its pathologies* 231: 111-122.

Baert, K., Devlieghere, F., Flyps, H., Oosterlinck, M., Ahmed, M., Rajkovic, A., Verlinden, B., Nicolaï, B., Debevere, J. and De Meulenaer, B. 2007. Influence of storage conditions of apples on growth and patulin production by *Penicillium expansum*. International Journal of Food Microbiology 119: 170-181.

Bandopadyay, R., Butler, D.R., Chandrasekhar, A., Reddy, R.K. and Navi, S.S. 2000. Biology epidemiology and management of sorghum grain mold. In: Chandrashekar A, Bandyopadhyay R, Hall AJ, editors. Technical and institutional options for sorghum grain mold management: proceedings of an international consultation, p. 34-71. ICRISAT: Andhra Pradesh India.

Battilani, P., Pieteri, A., Bertuzzi, T., Languasco, L., Giorni, P. and Kozakiewicz, Z. 2003. Occurrence of OTA-producing fungi in grapes grown in Italy. Journal of Food Protection 66: 633-636.

Bejaoui, H., Mathieu, F., Taillandier, P. and Lebrihi, A. 2006. Black *aspergilli* and ochratoxin A production in French vineyards. International Journal of Food Microbiology 111 (1): S46-S52.

Belaiche, T. 2001. Effects of contamination by *Aspergillus flavus* and *Aspergillus ochraceus* on olive quality. Industries alimentaires et agricoles 118: 27-29.

Bellí, N., Pardo, E., Marín, S., Farré, G., Ramos, A. J., and Sanchis, V. 2004. Occurrence of ochratoxin A and toxigenic potential of fungal isolates from Spanish grapes. Journal of the Science of Food and Agriculture 84: 541-546.

Bennett, J.W. and Klich, M. 2003. Mycotoxins. Clinical Microbiology Reviews 16: 497-516.

Bensassi, F., Zaied, C., Abid, S., Hajlaoui, M. R. and Bacha, H. 2010. Occurrence of deoxynivalenol in durum wheat in Tunisia. Food Control 21: 281-285.

Beyer, M., Klix, M.B. and Verreet J.A. 2007. Estimating mycotoxin contents of *Fusarium*-damaged winter wheat kernels. International Journal of Food Microbiology 119: 153-158.

Bhatnagar, D., Ehrlich, K.C. and Cleveland, T.E. 2003. Molecular genetic analysis and regulation of aflatoxin biosynthesis. Applied Microbiology and Biotechnology 61: 83-93.

Bouslimi, A., Bouaziz, C., Ayed-Boussema, I., Hassen, W. and Bacha, H. 2008. Individual and combined effects of ochratoxin A and citrinin on viability and DNA fragmentation in cultured Vero cells and on chromosome aberrations in mice bone marrow cells. Toxicology 251: 1-7.

Boutrif, E., Jemmali, M., Campbell, A.D. and Pohland, A.E. 1977a Aflatoxin in Tunisian foods and foodstuffs. Annales de la Nutrition et de l'Alimentation 31: 431-434

Boutrif, E., Jemmali, M., Pohland, A. E. and Campbell, A. D. 1977b. Aflatoxin in Tunisian Aleppo pine nuts. Journal of AOAC International 60: 747-748.

Chagas, G.M., Campello, A.P. and Kluppel, M.L.W. 1992. Mechanism of citrinin-induced dysfunction of mitochondria. Effects on respiration, enzyme activities and membrane potential of renal cortical mitochondria. Journal of Applied Toxicology 12: 123-129.

Chebil, S., Roudet, J., Ghorbel, A. and Dubos, B. 2004. Incidence de l'installation précoce de *Botrytis cinerea* sur le développement de la Pourriture grise du Muscat d'Italie dans le vignoble tunisien. Journal International des Sciences de la Vigne et du Vin 38: 131-138.

Chen, J., Mirocha, C.J., Xie, W., Hogge, L.R. and Olson, S.C. 1992. Production of the mycotoxin fumonisin B1 by *Alternaria alternata* f. sp. *lycopersici*. Applied and Environmental Microbiology 60: 847-852.

Chen, J., Dagher, S.M., Fisher, C.E., Grunow, W., Hatton, D.G. and Kawamura, Y. 2000. Evaluation of certain food additives and contaminants. WHO Technical Report Series 896(IEVIII): 1-127.

Chu, F.S. and Li, G.Y. 1994. Simultaneous occurrence of fumonisin B1 and other mycotoxins in moldy corn collected from the People's Republic of China in regions with high incidences of esophageal cancer. Applied and Environmental Microbiology 60: 847-852.

Ciegler, A., Detroy, R.W. and Lillejoj, E.B. 1971. Patulin, penicillic acid and other carcinogenic lactones. In A. Ciegler, S. Kadis, & S. J. Ajl (Eds.). Microbial toxins, pp. 409-434. New York: Academic Press.

Ciegler, A. 1977. Patulin. In J. V. Rodricks, C.W. Hesseltine, & M. A. Mehlman (Eds.), Mycotoxins in human and animal health, pp. 609-624. Park Forest South: Pathotox.

Clear, R.M. and Patrick, S.K. 2000. *Fusarium* head blight pathogens isolated from *Fusarium*-damaged kernels of wheat in western Canada, 1993 to 1998. Canadian Journal of Plant Pathology 22: 51-60.

Codex Alimentarius Commission. 1999. Codex Committee on Food Additives and Contaminants. 31st session, The Hague, the Netherlands, 22-26 March.

Codex Alimentarius Commission. 2012. Discussion paper on mycotoxins in sorghum. Joint FAO/WHO food standards program codex committee on contaminants in foods sixth session Maastricht, The Netherlands, 26-30 March 2012.

Cole, R.J. and Cox, R.H. 1981. The aflatoxins. Hand Book of Toxic Fungal Metabolites, pp. 1-66. Academic Press, (London) LDT.

Conkova, E., Laciakova, A., Pastorova, B., Seidel, H. and Kovac, G. 2001. The effect of zearalenone on some enzymatic parameters in rabbits. Toxicology Letters 121: 145-149.

Copetti, M.V., Pereira, J.I., Iamanaka, B.T., Pitt, J.I. and Taniwaki, M.H. 2010. Ochratoxigenic fungi and ochratoxin A in cocoa during farm processing. International Journal of Food Microbiology 143: 67-70.

Council for Agricultural Science and Technology (CAST). 1989. *Task Force Report* 116: 37.

Council for Agricultural Science and Technology (CAST). 2003. Mycotoxins: Risks in plant, animal and human systems. In J. L. Richard, & G. A. Payne (Eds.), Council for agricultural science and technology task force report No. 139, Ames, Iowa, USA, pp. 1-191.

Creppy, E.E. 2002. Update of survey, regulation and toxic effects of mycotoxins in Europe. Toxicology Letters 127: 19-28.

D'Mello, J.P.F. 2003. Food Safety contaminants and toxins, CABI Publishing, pp. 65.

De Moraes, M.H.P. and Luchese, R.H. 2003. Ochratoxin a on green coffee: Influence of harvest and drying processing procedures. Journal of Agricultural and Food Chemistry 51: 5824-5828.

Desjardins, A.E. and Proctor, R.H. 2001. Biochemistry and genetics of *Fusarium* toxins. In B. A. Summerell, J. F. Leslie, D. Backhaus, W. L. Bryden, & L. W. Burgess (Eds.), *Fusarium*–Paul E. Nelson memorial symposium, pp. 50-69 St. Paul, Minnesota, USA: APS Presse.

Devegowda, G., Raju, M. and Swang, H. 1998. Mycotoxins: novel solutions for the counteraction. Feedstuffs 70: 12-15.

Duarte, S. C., Lino, C. M. and Pena, A. 2010. Mycotoxin food and feed regulation and the specific case of ochratoxin A: a review of the worldwide status. Food Additives and Contaminants - Part A Chemistry, Analysis, Control, Exposure and Risk Assessment 27: 1440-1450.

Eaton, D.L. and Gallagher, E.P. 1994. Mechanisms of aflatoxins carcinogenesis. Annual Review of Pharmacology and Toxicology 34: 135-172.

Edwards, S.G., Pirgoziliev, S.R., Hare, M.C. and Jenkinson, P. 2001. Quantification of trichothecene-producing *Fusarium* species in harvested grain by competitive PCR to determine efficacies of fungicides against *Fusarium* head blight of winter wheat. Applied and Environmental Microbiology 67: 1575-1580.

Ei-Banna, A.A., Pitt, J.I. and Leistner, L. 1987. Production of mycotoxins by *Penicillium* species. System of Applied Microbiology 10: 42-46.

El Adlouni, C., Tozlovanu, M., Naman, F., Faid, M. and Pfohl-Leszkowicz, A. 2006. Preliminary data on the presence of mycotoxins (ochratoxin A, citrinin and aflatoxin B1) in black table olives ‘‘Greek style” of Moroccan origin. Molecular Nutrition & Food Research 50: 507-512.

El-Kady, I.A., El-Maraghy, S.S.M. and Mostafa, M.E. 1995. Natural occurrence of mycotoxins in different spices in Egypt. Folia Microbiologica 40: 297-300.

El-Maghraby, O.M.O., El-Kady, I.A. and Soliman, S. 1995. Mycoflora and *Fusarium* toxins of three types of corn grains in Egypt with special reference to production of trichothecene-toxins. Microbiological Research 150: 225-232.

El-Maghraby, O.M.O. 1996. Mycotoxins and mycoflora of rice in Egypt with special reference to trichothecenes production and control. Journal of Natural Toxins 5: 49-59.

El Mahgubi, A., Puel, O., Bailly, S., Tadrist, S., Querin, A., Ouadia, A., Oswald, I.P. and Bailly, J.D. 2013. Distribution and toxigenicity of *Aspergillus* section *Flavi* in spices marketed in Morocco. Food Control 32: 143-148.

Embaby, E.M., Nahed, M.A., Abd-El Hamid, N.H., Abdel-Galil, M.M., Yaseen, A.A. and Younos, M.A. 2012. Detection of fungi and mycotoxin affected wheat quality. Journal of Applied Sciences Research 8: 3382-3392.

Ennouari, A., Sanchis, V., Marín, S., Rahouti, M., and Zinedine, A. 2013. Occurrence of deoxynivalenol in durum wheat from Morocco. Food Control 32:115-118.

Eriksen, G.S. and Pettersson, H. 2004. Toxicological evaluation of trichothecenes in animal feed. Animal Feed Science and Technology 114: 205-239.

European Commission (EC). 2002. Commission Regulation (EC) No. 472/2002 of 12 March 2002 amending Regulation (EC) No. 466/2001 setting maximum levels for certain contaminants in foodstuffs. *Official Journal of the European Communities,* L75, 18-20.

European Commission (EC). 2006a. Commission Recommendation No 2006/576 of 17 August 2006 on the presence of deoxynivalenol, zearalenone, ochratoxin A, T-2 and HT-2 and fumonisins in products intended for animal feeding. Official Journal of the European Union, L 229, 7-9.

European Commission (EC). 2006b. Commission Regulation No. 1881/2006 of December 19th setting maximum levels of certain contaminants in foodstuffs. *Official Journal of the European Union No. L364/5 of December 20th.*

European Commission (EC). 2007. 1126/2007 of 28 September 2007 setting maximum levels for certain contaminants in foodstuffs as regards *Fusarium* toxins in maize and maize products. *Official Journal of the European Journal* L 255, 14-17.

European Commission (EC). 2010. Commission Regulation No 165/2010 of February 26 amending regulatio (EC) No 1881/2006. Setting maximum levels for certain contaminants in foodstuffs as regards aflatoxins. Official Journal of the European Union, L50,8-10 of February 27th.

Fadl Allah, E.M. 1998. Occurrence and toxigenicity of *Fusarium moniliforme* from freshly harvested maize ears with special references to fumonisin production in Egypt. Mycopathologia 140: 99-103.

Fakhfakh, M.M., Yahyaoui, A., Rezgui, S., Elias, E.M. and Daaloul, A. 2011. Identification and pathogenicity assessment of *Fusarium* spp. sampled from durum wheat fields in Tunisia. African Journal of Biotechnology 10: 6529-6539.

FAO (Food and Agriculture Organization of the United Nations). 1994. Corporate Document Repository. Sorghum and millet in Human health Retrieved on 04'05/2014 from www.fao.org/docrep/T0818E/T0818E0a. htm#Chapter%204%20–20Chemical%20composition%20and%20nutritive% 20value.

FAO (Food and Agriculture Organization of the United Nations). 2004a. Worldwide Regulations for Mycotoxins in Food and Feed in 2003. FAO Food and Nutrition paper, Vol. 81. FAO, Rome, Italy.

FAO (Food and Agriculture Organization of the United Nations). 2004b. Barley: Post-harvest Operations. The Central Research Institute for Field Crops, P.O.Box. 226, Ulus, Ankara,Turkey. FAO (Technical) Last reviewed: 15/06/2004.

FAO (Food and Agriculture Organization of the United Nations). 2011. Cereal supply and demand brief. In FAO cereal supply and demand situation. (July 2011).

Fernane, F., Sanchis, V., Marín, S. and Ramos, A.J. 2010. First report on mould and mycotoxin contamination of pistachios sampled in Algeria. Mycopathologia 170: 423-429.

Filali, A., Ouammi, L., Betbeder, A., Baudrimont, I., Benayada, A., Souleymani, R. and Creppy, E.E. 2001. Ochratoxin A in beverages from Morocco: A preliminary survey. Food Additives and Contaminants 18: 565-568.

Filali, A., Brtheder, A.M., Baudrimont, I., Benayada, A., Soueymani, R. and Creppy, E.E. 2002. Ochratoxin A in human plasma in Morocco: A preliminary survey. Human and Experimental Toxicology 21: 241-245.

Franceschi, S., Bidoli, E., Baron, A.E. and La Vecchia, C. 1990. Maize and risk of cancers of the oral cavity, pharynx and esophagus in Northeastern Italy. Journal of National Cancer Institute 82: 1407-1411.

Gaaloul, I., Riabi, S. and Ellouz-Ghorbel, R. 2011. Implementation of ISO 22000 in cereal food industry "SMID" in Tunisia. Food Control 22: 59-66

García-Cela, E., Ramos, A.J., Sanchis, V. and Marin, S. 2012. Emerging risk management metrics in food safety: FSO, PO. How do they apply to the mycotoxin hazard? Food Control 25: 797-808.

Gargouri Kammoun, L., Gargouri, S., Hajlaoui, M.R. and Marrakchi, M. 2009. Occurrence and Distribution of *Microdochium* and *Fusarium* Species Isolated from Durum Wheat in Northern Tunisia and Detection of Mycotoxins in Naturally Infested Grain. Journal of Phytopathology 157: 546-551.

Gelderblom, W.C., Marasas, W.F., Vleggaar, R., Thiel, P.G. and Cawood, M.E. 1992. Fumonisins: isolation, chemical characterization and biological effects. Mycopathologia 117: 11-16.

Ghali, R., Hmaissia-khlifa, K., Ghorbel, H., Maaroufi, K. and Hedili, A. 2008. Incidence of aflatoxins, ochratoxin A and zearalenone in tunisian foods. Food Control 19: 921-924.

Ghali, R., Hmaissia-Khlifa, K., Ghorbel, H., Maaroufi, K. and Hedilli, A. 2009. HPLC determination of ochratoxin A in high consumption Tunisian foods. Food Control 20: 716-720.

Ghali, R., Hmaissia-khlifa, K., Ghorbel, H., Maaroufi, K.and Hedili, A. 2010. Aflatoxin determination in commonly consumed foods in Tunisia. Journal of the Sciences of Food and Agriculture 90: 2347-2351.

Gilmour, M., and Lindblom, M. 2008. Management of ochratoxin A in the cocoa supply chain: A summary of work by the CAOBISCO/ECA/PCC working group on ochratoxin A. In J. F. Leslie, R. Bandyopadhyay, & A. Visconti (Eds.), Mycotoxins: Detection methods, management, public health and agricultural trade, pp. 231-243. Cambridge, USA: CABI.

Gizachew, D., Szonyi, B., Tegegne, A., Hanson, J. and Grace, D. 2016. Aflatoxin contamination of milk and dairy feeds in the Greater Addis Ababa milk shed, Ethiopia. Food Control 59: 773-779.

Glenn, A.E. 2007. Mycotoxigenic *Fusarium* species in animal feed. Animal Feed Science and Technology 137: 213-240.

Gourama, H. and Bullerman, L.B. 1988. Mycotoxin production by molds isolated from 'Greek-style' black olives. International Journal of Food Microbiolgy 6: 81-90.

Gourama, H. and Bullerman, L.B. 1995. *Aspergillus flavus* and *Aspergillus parasiticus*, aflatoxigenic fungi of concern in foods and feed. *a review.* Journal of Food Protection 58: 1395-1404.

Hajjaji, A., El Otmani, M., Bouya, D., Bouseta, A., Mathieu, F., Collin, S. and Lebrihi, A. 2006. Occurrence of mycotoxins (ochratoxin A, deoxynivalenol) and toxigenic fungi in Moroccan wheat grains: impact of ecological factors on the growth and ochratoxin A production. Molecular Nutrition & Food Research 50: 494-499.

Hernandez-Martínez, R. and Navarro-Blasco, I. 2010. Aflatoxin levels and exposure assessment of Spanish infant cereals. Food Additives and Contaminants 3: 275-288.

Hesseltine, C.W., Vandegraft, E., Fennell, D., Smith, M.L. and Shotwell, O.L. 1972. Aspergilli as Ochratoxin producers. Mycologia 64: 539-550.

Horie, Y. 1995. Productivity of ochratoxin A of *Aspergillus carbonarius* in *Aspergillus* section *Nigri*. Nippon Kingakukai Kaiho 36: 73-76.

Hussein, A.M.S., Kamil, M.M., Hegazy, N.A., Abo El-Nor, S.A.H. 2013. Effect of Wheat Flour Supplemented with Barely and/or Corn Flour on Balady Bread Quality. Polish Journal of Food Nutrition Sciences 63 (1): 11-18.

INORPI. 1983. List of Maximum Concentrations of Contaminants and Undesirable Substances. Tunisian Standard NT 117.02 .

International Agency for Research on Cancer (IARC). 1993. Monographs on the evaluation of carcinogenic risks to humansIn Some naturally occurring substances: Food items and constituents, heterocyclic aromatic amines and mycotoxins, Vol. 56. Lyon: International Agency for Research on Cancer, 489-521

International Agency for Research on Cancer (IARC). 1999. Monographs on the overall evaluations of carcinogenicity to humans. IARC monographs, Vols. 1-73 Lyon, France, 1-36.

International Agency for Research on Cancer (IARC). 2002. Monographs on the evaluation of the carcinogenic risk of chemicals to humans, 82 pp. 169-345). Lyon, France: International Agency for Research on Cancer (WHO).

Intergovernmental Panel on Climate Change (IPCC). 2012. Managing the risks of extreme events and disasters to advance climate change adaptation. In: Field, C., Barros, V., Stocker, T., Qin, D., Dokken, D., Ebi, K., Mastrandrea, M., Mach, K., Plattner, G., Allen, S., Tignor, M., Midgley, P. (Eds.), A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York.

Iwahashi, H.K. 2007. Evaluation of toxicity of the mycotoxin citrinin using yeast ORF DNA microarray and oligo DNA microarray. BMC Genomics 5: 8-95.
Jouany, J.P. 2007. Methods for preventing, decontaminating and minimizing the toxicity of mycotoxins in feeds. Animal Feed Science and Technology 137: 342-362.
Juan, C., Zinedine, A., Soriano, J.M., Moltó. J.C, Idrissi, L. and Mañes, J. 2008. Aflatoxins levels in dried fruits and nuts available in Rabat-Salé area, Morocco. Food Control 19: 849-853.
Juan, C., Ritieni, A. and Mañes, J. 2012. Determination of trichothecenes and zearalenones in grain cereal, flour and bread by liquid chromatography tandem mass spectroscopy. Food Chemistry 134(4): 2389-2397.
Klich, M.A. 2007. Environmental and developmental factors influencing aflatoxin production by *Aspergillus flavus* and *Aspergillus parasiticus*. Mycoscience 48: 72-80.
Kosiak, E.B., Holst-Jensen, A., Rundberget, T., González-Jaén, M.T., and Torp, M. 2005. Morphological, chemical and molecular differentiation of *Fusarium equiseti* isolated from Norwegian cereals. International Journal of Food Microbiology 99: 195-206.
Krogh, P.H., Hald, B., Plestina, R. and Ceovic, S. 1977. Balkan endemic nephropathy and foodborne ochratoxin A: preliminary results of survey of foodstuffs. Acta Pathlologica, Microbiologica et Immunologica Scandinavica 85: 238-240.
Kurata, H. 1990. Mycotoxins and mycotoxicoses. IN A. E. Pohland, V.R. Dowell, J.L. Richards (EDs.), Microbial toxins in foods and feeds, pp. 249-259. New York, USA: Plenum Press.
Kurtzman, C. D., Horn, B. W., and Hessetline, C. W. 1987. *Aspergillus nomius*, a new aflatoxin producing species related to *Aspergillus flavus* and *Aspergillus tamari* Antonie van Leeuwenhoek. Journal of Microbiology 53: 158-174.
Lahouar, A., Crespo-Sempere, A., Marín, S., Saïd, S. and Sanchis, V. 2015. Toxigenic molds in Tunisian and Egyptian sorghum for human Consumption. Journal of Stored Products Research 63: 57-62.
Lahouar, A., Marin, S, Crespo-Sempere, A., Saïd, S. and Sanchis, V. 2016. Effects of temperature, water activity and incubation time on fungal growth and aflatoxin B1 production by toxinogenic *Aspergillus flavus* isolates on sorghum seeds. Revista Argentina de Microbiologia 48(1): 78-85.
Lahouar, A., Marin, S., Crespo-Sempere, A., Saïd, S. and Sanchis, V. 2017. Influence of temperature, water activity and incubation time on fungal growth and production of ochratoxin A and zearalenone by toxigenic *Aspergillus tubingensis* and *Fusarium incarnatum* isolates in sorghum seeds. International Journal of Food Microbiology 242: 53-60.
Lahoum, A., Verheecke-Vaessen, C., Bouras, N., Sabaou, N., Mathieu, F. 2017. Taxonomy of mycelial actinobacteria isolated from Saharan soils and their efficiency to reduce aflatoxin B1 content in a solid-based medium. Annals of Microbiology 67 (3): 231-237.
Lasram, S., Bellí, N., Chebil, S., Zghonda, N., Mliki, A., Sanchis, V. and Ghorbel, A. 2007. Occurrence of ochratoxigenic fungi and ochratoxin A in grapes from a Tunisian vineyard. International Journal of Food Microbiology 114: 376-379.
Lasram, S., Oueslati, S., Valero, A., Marin, S., Ghorbel, A.W. and Sanchis, V. 2010. Water Activity and Temperature Effects on Fungal Growth and Ochratoxin A Production by Ochratoxigenic *Aspergillus carbonarius* Isolated from Tunisian Grapes. Journal of Food Science 75 (2): 89-97.
Lasram, S., Oueslati, S., Chebil, S., Mliki, A. and Ghorbel, A. 2013. Occurrence of ochratoxin A in domestic beers and wines from Tunisia by immunoaffinity clean-up and liquid chromatography. Food Additives and Contaminants: Part B: Surveillance 6: 1-5.
Lasram, S., Hamdi, Z., Chenenaoui, S., mliki, A. and Ghorbel, A.W. 2016. Comparative study of toxigenic potential of *Aspergillus flavus* and *Aspergillus niger* isolated from Barley as

affected by temperature, water activity and carbon source. Journal of Stored Products Research 69: 58-64.

Leslie, J.F. and Summerell, B.A. 2006. The *Fusarium* Laboratory Manual. first ed. Blackwell Publishing, p. 169-249. Iowa, USA.

Li, F., Xu, G., Li, Y. and Chen, Y. 2003. Study on the production of citrinin by *Monascus* strains used in food industry. Wei Sheng Yan Jiu 32: 602-605.

Liu, B.H., Yu, F.Y., Wu, T.S., Li, S.Y., Su, M.C., Wang, M. C. and Shih, S. M. 2003. Evaluation of genotoxic risk and oxidative DNA damage in mammalian cells exposed to mycotoxins, patulin and citrinin. Toxicology and Applied Pharmacology 191: 255-263.

Maaroufi, K., Achour, A., Hammami, M., El-May, M., Betbeder, A.M., Ellouz, F., Creppy, E.E. and Bacha, H. 1995. Ochratoxin A in human blood in relation to nephropathy in Tunisia. Human & Experimental Toxicology 14: 609-615.

Maaroufi, K. Achour, A., Zakhama, A., Ellouz, F., El may, M., Creppy, E.E. and Bacha, H. 1996. Human nephropathy related to ochratoxin A in Tunisia. Journal of Toxicology 15: 223-237.

Madbouly, A.K., Ibrahim, M.I.M., Sehab, A.F. and Abdel-Wahhab, M.A. 2012. Co-occurrence of mycoflora, aflatoxins and fumonisins in maize and rice seeds from markets of different districts in Cairo, Egypt. Food Additives and Contaminants: Part B Surveillance 5: 112-120.

Manova, R. and Mladenova, R. 2009. Incidence of zearalenone and fumonisins in Bulgarian cereal production. Food Control 20: 362-365.

Marasas, W.F., Kellerman, T.S., Gelderblom, W.C., Coetzer, J.A., Thiel, P.G. and Van Der Lugt, J.J. 1988. Leukoencephalomalacia in a horse induced by fumonisin B1 isolated from *Fusarium moniliforme*. Onderstepoort Journal of Veterinary Research 55: 197-203.

Marin, S., Belli, N., Lasram, S., Chebil, S., Ramos, A. J., Ghorbel, A. and Sanchis, V. 2006. Kinetics of Ochratoxin A Production and Accumulation by *Aspergillus carbonarius* on Synthetic Grape Medium at Different Temperature Levels. Journal of Food Science 71 (6): 196-200.

Mazumdar, P.M., Sasmal, D. 2001. Mycotoxins – limits and Regulations. Ancient Science of life 200: 1-19.

Melki Ben Fredj, S., Chebil, S., Lebrihi, A., Lasram, S., Ghorbel, A. and Mliki, A. 2007. Occurrence of pathogenic fungal species in Tunisian vineyards. International Journal of Food Microbiology 113: 245-250.

Miller, J.D. 1995. Fungi and mycotoxins in grain: Implications for stored product research. Journal of Stored Product Research 31: 1-16.

Miraglia, M. and Brera, C. 2000. Mycotoxins in Grains and Related Products. In Leo. M. L. Nollet (Ed.), Food analysis by HPLC (2nd ed.), pp. 493-522. New York: Marcel Dekker, Inc.

Miraglia, M., Marvin, H.J.P., Kleter, G.A., Battilani, P., Brera, C., Coni, E., Cubadda, F., Croci, L., De Santis, B., Dekkers, S., Filippi, L., Hutjes, R.W.A., Noordam, M.Y., Pisante, M., Piva, G., Prandini, A., Toti, L., van den Born, G.J. and Vespermann, A. 2009. Climate change and food safety: an emerging issue with special focus on Europe. Food and Chemical Toxicology 47: 1009-1021.

Monaci, L. and Palmisano, F. 2004. Determination of ochratoxin A in foods: state of the art and analytical challenges. Analytical and Bioanalitycal Chemistry 378: 96-103.

Moss, M.O. and Long, M.T. 2002. Fate of patulin in the presence of yeast *Saccharomyces cerevisiae*. Food Additives and Contaminants 19: 387-399.

Mousa, W., Ghazali, F.M., Jinap, S., Ghazali, H.M. and Radu, S. 2013. Modeling growth rate and assessing aflatoxins production by *Aspergillus flavus* as a function of water activity and temperature on polished and brown rice. Journal of Food Science 78 (1): 56-63.

Olivier, R. E., Cai, X., Friesen, T. L., Halley, S., Stack, R. W. and Xu, S. S. 2008. Evaluation of *Fusarium* Head Blight Resistance in tetraploid wheat (*Triticum turgidum* L.). Crop Science 48: 213-222.

Oueslati, S., Romero-Gonzalez, R., Lasram, S., Garrido-frenich, A., Martinez-Vidal, J.L. 2012. Multi-mycotoxin determination in cereals and derived products marketed in Tunisia using ultra-high performance liquid chromatografy coupled to triple quadrupole mass spectrometry. Food and Chemical Toxicology 50: 2376-2381.

Oueslati, S., Blesa, J., Molto, J.C., Ghorbel, A. and Mañes, J. 2014. Presence of mycotoxin in sorghum and intake estimation in Tunisia. Food Additives and Contaminants: Part A 31: 307-318.

Parry, D.W., Jenkinson, P. and McLeod, L. 1995. *Fusarium* ear blight (scab) in small grain cereals – a review. Plant Pathology 44: 207-238.

Paterson, R. R. M. and Lima, N. 2010. How will climate change affect mycotoxins in food? Food Research International 43(7): 1902-1914.

Perrone, G., Susca, A., Cozzi, G., Ehrlich, K., Varga, J., Frisvad, J.C., Meijer, M., Noonim, P., Mahakamchanakul, W. and Samson, R.A. 2007. Biodiversity of *Aspergillus* species in some important agricultural products. Studies in Mycology 59: 53-66.

Perrone, G., Varga, J., Susca, A., Frisvad, J.C., Stea, G., Kocsubé, S., Tóth, B., Kozakiewicz, Z., Samson, R.A. 2008. *Aspergillus uvarum* sp. nov., an uniseriate black *Aspergillus* species isolated from grapes in Europe. International Journal of Systematic and Evolutionary Microbiology 58: 1032-1039.

Pestka, J.J. 2007. Deoxynivalenol: toxicity, mechanisms and health risks *Fusarium* and their In D. P. Morgavi & R. T. Riley (Eds.), toxins: Mycology, occurrence toxicity, control and economic impact. Animal feed science and technology 137: 283-298.

Pestka, J.J. 2010. Deoxynivalenol: mechanisms of action, human exposure, and toxicological relevance. Archives of Toxicology 84: 663-679.

Pfohl-Leszkowicz, A., Petkova-Bocharova, T.K., Chernozemsky, I.N. and Castegnaro, M. 2002. Balkan endemic nephropathy and associated urinary tract tumors: A review on etiological causes and the potential role of mycotoxins. Food Additives and Contaminants 19: 282-302.

Pier, A.C., Richard, J.L. 1992. Mycoses and mycotoxicoses of animals caused by Aspergilli. In J.W. Bennett, & M. A. Klich (Eds.), *Aspergillus*: biology and industrial applications, pp. 233-267. Maryland: Butterworth-Heinemann.

Pitt, J. 1987. *Penicillium viridicatum*, *Penicillium verrucosum* and production of ochratoxin A. Applied and Environmental Microbiology 35: 266-269.

Pitt, J.I. and Hocking, A.D. 1997. Fungi and food spoilage (2nd ed.). London: Blackie Academic and Professional.

Pitt, D.B., Plestina.J.I, Shepard, R., Solfrizzo, G., Verger, M., Walker, P.J.P. 2001. Safety evaluation of certain mycotoxins in food. In Joint FAO/WHO Expert Committee on Food Additives (JECFA) Rome: Food and Agriculture Organization, pp. 281.

Placinta, C. M., D'Mello, J. P. F., MacDonald, A. M. C. 1999. A review of worldwide contamination of cereal grains and animal feed with *Fusarium* mycotoxins. Animal Feed Science and Technology 78: 21-37.

Pleadin, J., Vulic, Persi, N., Skrivanko, M., Capek, B. and Cvetnic, Z. 2014. Aflatoxin B1 occurrence in maize sampled from Croatian farms and feed factories during 2013. Food Control 40: 286-291.

Prandini, A., Transini, G., Sigolo, S., Filippi, L., Laporta, M. and Piva, G. 2009. On the occurrence of aflatoxin M1 in milk and dairy products. Food and Chemical Toxicology 47: 984-991.

Rheeder, J.P., Marasas, W.F.O., Thiel, P.G., Sydenham, E.W., Shepard, G.S. and Van Schalkwyk, D.J. 1992. *Fusarium moniliforme* and fumonisins in corn in relation to human oesophageal cancer in Transkei. Phytopathology 82: 353-357.

Rheeder, J.P., Marasas, W.F.O. and Vismer, H.F. 2002. Production of fumonisin analog by *Fusarium* species. Applied and Environmental Microbiology 68: 2101-2105.

Riba, A., Mokrane, S., Mathieu, F., Lebrihi, A. and Sabaou, N. 2008. Mycoflora and ochratoxin A producing strains of *Aspergillus* in Algerian wheat. International Journal of Food Microbiology 122: 85-92.

Riba, A., Bouras, N., Mokrane, S., Mathieu, F., Lebrihi, A. and Sabaou, N. 2010. *Aspergillus* section *Flavi* and aflatoxins in Algerian wheat and derived products. Food and Chemical Toxicology 48: 2772-2777.

Romani, S., Sacchetti, G., Chaves Lopez, C., Pinnavaia, G.G. and Dalla Rosa, M. 2000. Screening on the occurrence of ochratoxin A in green coffee beans of different origins and types. Journal of Agricultural and Food Chemistry 48: 3616-3619.

Roussos, S., Zaouia, N., Salih, G., Tantaoui-Elaraki, A., Lamrani, K., Cheheb, M., Hassouni, H., Verhé, F., Perraud-Gaime, I., Augur, C. and Ismaili-Alaoui, M. 2006. Characterization of filamentous fungi isolated from Moroccan olive and olive cake: Toxinogenic potential of *Aspergillus* strains. Molecular Nutrition and Food Research 50: 500-506.

Said, A., Mabrouk, I., Afdhal, B., Fredj, L., Hani, K. and Jemmali, M. 1999. Les mycotoxines en Tunisie: résultats de quatre années d'expertises. Microbiologie et Hygiène Alimentaire 11: 29-35.

Samson, R.A, Hoeckstra, E.S., Frisvad, J.C. and Filtemborg, O. 2000. Introduction to food-and airborne fungi. 6th ed. Utrecht: Centraalbureau voor schimmelcultures.

Schroeder, H.W. and Hein, H.J. 1975. A note on zearalenone in grain sorghum. Cereal Chemistry Journal 52: 751-752.

Serrano, A.B, Font, G., Ruiz, M.J. and Ferrer, E. 2012. Co-occurrence and risk assessment of mycotoxin in food and diet from Mediterranean area. Food Chemistry 135: 423-429.

Shephard, G.S., Marasas, W.F., Leggott, N.L., Yazdanpanah, H., Rahimian, H. and Safavi, N. 2000. Natural occurrence of fumonisins in corn from Iran. Journal of Agriculture and Food Chemistry 48: 1860-1864.

Sherif, S.O., Salama, E.E. and Abdel-Wahhab, M.A. 2009. Mycotoxins and child health: The need for health risk assessment. International Journal of Hygiene and Environmental Health 212: 347-368.

Shier, W.T., Sier, A.C., Xie, W., Mirocha, C.J. 2001. Structure-activity relationships for human oestrogenic activity in zearalenone mycotoxins. Toxicon 39: 1435-1438.

Simpson, D.R., Weston, G.E., Turner, J.A., Jennings, P. and Nicholson, P. 2001. Differential control of head blight pathogens of wheat by fungicides and consequences for mycotoxin contamination of grain . European Journal of Plant Pathology 107: 421-431.

Speijers, G.J.A. 2004. Patulin. In N. Magan, & M. Olsen (Eds.), Mycotoxins in fooddetection and control, pp. 339-352. Cambridge, England: Woodhead Publishing Ltd.

Studer-Rohr, I., Schlatter, J. and Dietriech, D. 2000. Kinetic parameters and intraindividual fluctuations of ochratoxin A plasma levels in humans. Archives of Toxicology 74: 499-510.

Sultan, Y. and Magan, N. 2010. Mycotoxigenic fungi in peanuts from different geographic regios of Egypt. Mycotoxin Research 26: 133-140.

Sydenham, E.W., Thiel, P.G., Marasas, W.F.O., Shepard, G.S., Van Schalkwyk, D.J. and Koch, K.R. 1990. Natural occurrence of some *Fusarium* mycotoxins in corn from low and high esophageal cancer prevalence areas of Transkei, Southern Africa. Journal of Agriculture and Food Chemistry 38: 1900-1903.

Tam, J., Mankotia, M., Mably, M., Pantazopoulos, P., Neil, R.J., Calway, P. and Scott, P.M. 2006. Survey of breakfast and infant cereals for aflatoxins B1, B2, G1 and G2. Food Additives and Contaminants 23: 693-699.

Tantaoui-Elaraki, A., Le Tutour, B. and Aboussalim, A. 1983a. Consequences of the contamination of olives by toxic *Aspergillus* on the quantity and the quality of the extracted oil. Revue française des corps gras 11: 473-476.

Tantaoui-Elaraki, A., Le Tutour, M., Bouzid, M. and Keddani, M. 1983b. Contamination des olives noires Facon Grece par les spores d'*Aspergillus* toxigenes et leur toxins. Journal des Industrie Agricoles et Alimentaires Cahier Scientifique et Technique 100: 997-1000.

The European Parliament and Council. 2002. Directive 2002/32/EC of the European Parliament and of the Council of 7May 2002 on undesirable substances in animal feed. Official Journal of the European Union, L 140, 10-22.

Thiel, P.G., Marasas, W.F.O., Sydenham, E.W., Shepar, G.S. and Gelderblom, W.C.A. 1992. The implications of naturally occurring levels of fumonisins in corn form human and animal health. Mycopathologia 117: 3-9.

Turner, N. W., Sabrahmanyam, S. and Piletsky, S. A. 2009. Analytical methods for determination of mycotoxins: A review. Analytica Chimica Acta 2: 168-180.

Unusan, N. 2006. Occurrence of aflatoxin M1 in UHT milk in Turkey. Food and Chemical Toxicology 44(11): 1897-1900.

Van Egmond, H.P., Schothorst, R.C., Jonker, M.A. 2007. Regulations relating to mycotoxins in food: Perspectives in a global and European context. Analytical and Bioanalytical Chemistry 389: 147-157.

Veiga, A.A. 1986. Aspectos económicos de cultura de sorgo. Informe Agropecuario 12: 3-5.

Vismer, H.F., Shephard, G.S., Rheeder, J.P., van der Westhuizen, L. and Bandyopadhyay, R. 2015. Relative severity of fumonisin contamination of cereal crops in West Africa. Food Additive and Contaminants: Part A 32(11): 1952-1958.

Wagacha, J. M. and Muthomi, J. W. 2008. Mycotoxin problem in Africa: Current status, implications to food safety and health and possible management strategies. International Journal of Food Microbiology 124: 1-12.

Waliyar, F., Ravinder, R.C., Alur, A.S., Reddy, B.V.S., Reddy, A.R., Gowda, C.L.L. 2007. Management of grain mold and mycotoxins in sorghum. Patancheru, Andhra Pradesh, India: International Crops Research Institute for Semi-Arid Tropics, p. 32.

WHO. 1990. Environmental health criteria 105 selected mycotoxins: ochratoxins, trichothecenes, ergot, trichothecenes. International Programme on Chemical Safety (IPCS) Geneva, World Health Organization, 71-154.

Wogan, G.W. and Paglialunga, S. 1974. Carcinogenicity of synthetic aflatoxin M1 in rats. Food and Cosmetic Toxicology 12: 381-384.

Wouters, M.F.A. and Speijers, G.J.A. 1996. Patulin. In Food additives series 35. Toxicological evaluation of certain food additives and contaminants, pp. 337-402. Geneva, Switzerland: World Health Organisation.

Wurgler, F.E., Friederich, U. and Schlatter, J. 1991. Lack of mutagenicity of ochratoxin A and B, citrinin, patulin and cystine in *Salmonella typhimurium* TA102. Mutation Research 261: 209-216.

Youssef, M.S., El-Maghraby, O.M.O. and Ibrahim, Y.M. 2008. Mycobiota and Mycotoxins of Egyptian Peanut (*Arachis hypogeae* L.) Seed. International Journal of Botany 4: 349-360.

Zaied, C., Abid, S., Zorgui, L., Bouaziz, C., Chouchane, S., Jomaa, M. and Bacha, H. 2009. Natural occurrence of ochratoxin A in Tunisian cereals. Food Control 20: 218-222.

Zaied, C., Zouaoui, N., Bacha, H. and Abid, S. 2012a. Natural occurrence of citrinin in Tunisian wheat grains. Food Control 28: 106-109.
Zaied, C., Zouaoui, N., Bacha, H. and Abid, S. 2012b. Natural occurrence of zearalenone in Tunisian wheat grains. Food Control 25: 773-777.
Zaied, C., Abid, S., Hlel, W. and Bacha, H. 2013. Occurrence of patulin in apple-based-foods largely consumed in Tunisia. Food Control 31: 263-267
Zimmerli, B. and Dick, R. 1996. Ochratoxin A in table wine and grape juice: occurrence and risk assessment. Food Additives and Contaminants 13: 655-668.
Zinedine, A., Betbeder, A.M., Faid, M., Benlemlih, M., Idrissi, L. and Creppy, E.E. 2004. Ochratoxin A: Determination in dried fruits and black olives from Morocco. Alimentaria 359: 73-76.
Zinedine, A., Faid, M. and Benlemlih, M. 2005. *In Vitro* Reduction of Aflatoxin B1 by Strains of Lactic Acid Bacteria Isolated from Moroccan Sourdough Bread. International Journal of Agriculture and Biology 7(1): 67-70.
Zinedine, A., Brera, C., Elakhdari, S., Catano, C., Debegnach, F., Angelini, S., De Santis, B., Faid, M., Benlemlih, M., Minardi, V., Miraglia, M. 2006. Natural occurrence of mycotoxins in cereals and spices commercialized in Morocco. Food Control 17: 868-874.
Zinedine, A., Soriano, J. M., Juan, C, Mojemmi, B., Moltó, J. C., Bouclouze, A., Cherrah, Y., Idrissi, L., El Aouad, R. and Mañes, J. 2007. Incidence of ochratoxin A in rice and dried fruits from Rabat and Salé area, Morocco. Food Additives and Contaminants 24: 285-291.
Zinedine, A., Gonzales-Osnaya, L., Soriano, J.M., Moltó, J.C., Idrissi, L., and Mañes, J. 2007. Presence of aflatoxin M1 in pasteurized milk from Morocco. International Journal of Food Microbiology 114: 25-29.
Zinedine, A., Juan, C., Soriano, J.M., Moltó, J.C., Idrissi, L. and Mañes, J. 2007. Limited survey for the occurrence of aflatoxins in cereals and poultry feeds from Morocco. International Journal of Food Microbiology 115: 124-127.
Zinedine, A. and Mañes, J. 2009. Occurrence and legislation of mycotoxins in food and feed from Morocco. Food Control 20: 334-344.
Zohri, A.A. and Abdel-Gawad, K.M. 1993. Survey of mycoflora and mycotoxins of some dried fruits in Egypt. Journal of Basic Microbiolgy 33: 279-288.

Table 1. Maximum levels of mycotoxins in various foodstuffs for human (European Commission,2002 ; 2006b ; 2007 ; 2010) and animal consumption (The European Parliament and Council, 2002; European Commission, 2006a)

Mycotoxin	Food commodity	Maximum limits (µg/kg)
Aflatoxin B1	Cereals and cereal-based-food for human consumption	2
	Unprocessed corn and rice intended for human consumption	5
	Raw material for animals	20
	Spices	5
	Dried fruits for direct consumption	2
	Peanuts	2
	Almonds and pistachios	8
Aflatoxin B1, B2, G1 and G2	All cereals and cereal-based-food intended for human consumption	4
	Unprocessed corn and rice for human consumption	10
	Spices	10
	Dried fruits for direct consumption	4
	Peanuts	4
	Almonds, pistachios and dried figs	10
Aflatoxin M1	liquid milk	0.05
Deoxynivalenol	Unprocessed cereals other than durum wheat, maize and oats	1250
	Unprocessed durum wheat and oats	1750
	Cereals intended for direct human consumption, flour, bran and germ in the form of a finished product for direct human consumption	750
	Bread, pastries, biscuits, cereal snacks and breakfast cereals	500
	Processed cereal-based foods and foods for infants and young children	250
	Cereals and cereal products for animals	8000
	Maize products for animals	12000
Zearalenone	Unprocessed cereals other than maize	100
	Unprocessed corn	350
	Cereals intended for direct human consumption, flour, bran and germ in the form of a finished product for direct human consumption	75
	Bread, pastries, biscuits, cereal snacks and breakfast cereals with the exception of maize products	50
	Corn intended for direct human consumption, snakes and breakfast products based on corn	100
	Processed cereal-based foods and foods for infants and young children	20
	Cereals and cereal products for animals	2000
	Corn products intended for animals	3000
Ochratoxin A	Unprocessed cereals	5
	Unprocessed cereal based-food, processed cereals and cereal products intended for direct human consumption	3
	Processed cereal-based foods and foods for infants and young children	0.05
	Cereals and cereal products for animals	250
	Instant coffee	10

	Roasted coffee beans	5
	Wines and grape juice	2
	Dried fruits for direct consumption	10
Fumonisin B1 and B2	Maize and maize-based food for direct human consumption	1000
	Corn-based snacks and breakfast cereals	800
	Processed maize-based foods for infants and young children	200
	Maize and maize products for animals	60

Table 2. Maximum levels of mycotoxins (µg/kg) in various foods destined for humans in North Africa countries

Mycotoxin	Food commodity	Morocco	Tunisia	Algeria	Egypt
Aflatoxin B1	Wheat flour	3			
	Cereals	10	2	10	5
	Corn				10
	Peanuts, pistachios, almonds and nuts	1			
	Peanuts and oilseeds				5
Aflatoxin B1, B2, G1 and G2	Cereals other than maize				10
	Maize				20
	Peanuts and oilseeds				10
Aflatoxin M1	Milk intended for adults	0.05			0.5
	Milk intended for children	0.03			
Ochratoxin A	Cereals	30			
	Coffee				5
Zearalenone	Cereals	200			
Deoxynivalenol	Wheat and wheat flour				700
	Barley and barley flour				1000